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THE FREEZING PRESERVATION OF CITRUS FRUITS AND JUICES*

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In the U. S. Fruit and Vegetable Products Laboratory, at Weslaco, Texas, investigations are conducted on the utilization of fruit and vegetable crops by canning, freezing, drying, and fermenting, and also upon the recovery of by-products and the disposal of wastes and residues. Investigations of the canning and freezing of fruits and vegetables are in cooperation with the Texas Agricultural Experiment Station.

As in all laboratories where citrus products are investigated, the preservation of orange juice with minimum alteration of flavor and food value has received consideration. It has been observed that after screening and deaeration, juice reamed from clean, sound, ripe Valencia oranges may be preserved satisfactorily by rapidly heating to 200° F, rapidly cooling to 180° F, sealing in tin or glass containers, from which oxygen is excluded, rapidly cooling and storing at temperatures below 60° F.

The slight modification in flavor caused by flash heating is not objectionable to most people, but storage of the canned juice at warm temperatures results in rapid deterioration, even of juice which is carefully prepared. The rate of deterioration decreases as storage temperatures are reduced, which lead to the testing of freezing storage as a means of preserving juice without heat treatment, depending upon low temperature to inhibit spoilage and enzymic deterioration.

Tests showed that the properly prepared juice of Valencia oranges, filled in containers which afforded protection from oxidation and drying, might be stored at 0° F as long as five years without appreciable change in flavor. However, frozen orange juice has not been commercially exploited to the extent which might have been anticipated. Before freezing, and after thawing, the juice is subject to rapid deterioration. Improper handling at any stage of preparation, during storage, or after defrosting results in objectionable changes in the taste.

The difficulty of educating individual consumers in proper methods for defrosting and serving frozen juice has largely restricted the profitable market to the institution trade, including hospitals, sanitaria, drink stands, and school, hotel, club and public restaurants, where defrosting is properly timed and the serving of the beverage is carefully controlled.

Satisfactory methods for preparing and freezing grapefruit and orange sections and grapefruit, orange and lemon juices have been demonstrated. Tests have included Marsh, Duncan and Red Blush grapefruit, and Valencia, Parson Brown, Hamlin, Pineapple, and Navel oranges. The following outline describes methods which have been found satisfactory by investigators and commercial operators:

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Varietal Adaptability. Marsh and Duncan grapefruit varieties are suitable for preparing frozen juice. These varieties and pink, or red bud variants are suitable for frozen sections or hearts.

Valencia is the best orange variety for frozen juice. Other varieties which have been tested are listed in the order of preference: Temple, Hamlin, Parson Brown, and Navel. Navel orange juice may develop a bitter flavor during storage. Manderin oranges are used almost exclusively for preparing sections.

Eureka and Lisbon lemons have been commercially frozen. Limited tests of the Meyers lemon indicated that juice of this variety is not as well adapted to freezing preservation.

Harvesting and Preparation of the Fruit. Fruit should preferably be harvested by hand and placed in picking sacks. Unless drops are carefully removed from the ground, the practice of shaking trees, or of dropping pulled fruit to the ground to be subsequently gathered in field boxes, presents a hazard of including spoiled fruit. Fruit should not be allowed to lie on the ground or sit in picking boxes exposed to direct sun light, as this will lower the quality of the juice.

Fruit should be sound, mature, and free from decay. Upon arrival at the plant the fruit should be thoroughly washed with strong sprays of water and vigorous brushing, and all softened, decayed or otherwise damaged fruit removed on sorting belts. Fruit is ordinarily immersed in a solution containing 200 parts per million of active chlorine. Excess chlorine is removed by rinsing with potable water immediately before the fruit goes to the extractors. The bacterial count in the finished product should not exceed 100,000 living cells per cubic centimeter, and may be held to one fifth of that number if proper precautions are observed.

Equipment. Stainless steel, chromium, Inconel, Nickel, tin, aluminum, glass or porcelain enamel should be used for equipment coming in contact with the juice. Stainless steel (18-8) is most commonly used. Copper, zinc, and iron are particularly objectionable and should never be used.

Plant Sanitation. Plant sanitation is important to prevent spoilage. All equipment, juice lines and floors should be washed with clean water and then steamed. As an extra precaution flushing with a solution containing 200 to 1000 p. p. m. of chlorine immediately before and after operation of the plant is found of value. Any wood coming in contact with the juice or floor drainings should be kept sealed with waterproof varnish. Floors should be sloped to drain freely, and facilities for screening and removing sewage and canning residues should be designed to permit sanitary, trouble free operation. Plants should be screened to exclude house and vinegar flies. Health and cleanliness of employees cannot be overemphasized, as products receive no heat treatment to destroy pathogenic or other organisms.

Extraction of Juice. Grapefruit, orange and lemon juices may be extracted, screened, deaerated and frozen by similar methods. Fruit may be precooled to 40° F before extraction of the juice, although in some plants this practice is unnecessary, as the total time elapsing between extraction and freezing is only a few minutes, and flavor changes are slight.

The juice should be extracted in such a manner as ti minimize the quantity of oil, pectin, pectic enzymes, and bitter substances incorporated from the peel and rag. Laboratory tests have shown that if the peel is puffed with steam, and removed by hand, as for segment canning, the juice may be extracted by any method of pressing which avoids tearing and grinding.

The juice may be extracted by hand, pressing halved fruit against rapidly revolving ribbed burs or cones. Mechanical extractors which duplicate the hand reaming operation are satisfactory, but mechanical devices which depend principally upon pressing halved or quartered fruit do not yield a product suitable for freezing preservation. Steaming of whole fruit for one minute results in volatilization of sufficient peel oil to make it possible to use this type of press in producing canned juice, which complies with the tentative requirements for fancy grades, but for freezing preservation-extractors which incorporate anyappreciable quantity of peel oil should be avoided.

When an automatic juice extractor is used, careful checking of the oil content of the juice is necessary, as excessive oil will lower the quality.

After extraction, the juice should be handled in clean, closed rooms with as little delay as possible.

Screening. The extracted juice is screened to remove seeds, intersectional membrane and pulp. Among the screen designs used are: 1. Flat and inclined plane vibrating screens, depending upon gravity and impact to secure separation. 2. Slowly rotating cylindrical (or hexagonal) screens, depending upon gravity to obtain separation. 3. Stationary cylindrical screens provided with rapidly rotating brushes, paddles, tapered screws, or other agitating devices, depending upon centrifugal force, impace, or pressure to obtain separation of the juice.

Methods which minimize pressing and grinding of seeds, peel, core and membrane result in juice of best flavor and texture. In the usual practice the finished juice contains 5 to 15 per cent of suspended solids when measured by the method described in the tentative grades for canned grapefruit juice promulgated by the U. S. Agricultural Marketing Service.

A continuous, sanitary, self-cleaning screen of nominal cost consists of two cylindrical (or hexagonal) reel-type screens, the inner screen of 12 mesh (0.06" opening) stainless steel, the outer screen usually of 40 mesh (0.0155" opening) to give the finished juice the desired content of suspended solids. In a convenient arrangement, the 12 mesh screen is approximately one foot in diameter, six feet long, and driven by a ring gear attached to the charging end. The cylinder, or hexagon, is inclined slightly toward the discharge end and provided with three one inch ribs attached lengthwise to the inner surface to tumble the seed and rag, thus promoting free draining without grinding or pressing. The cylinder (or hexagon) of finer mesh screen, having a diameter six inches greater, surrounds the coarser screen, and is fixed to the inner screen so that both are rotated by the drive through the ring gear. The doubly screened juice is collected in a stainless steel pan,

from which it flows by gravity, or is pumped to accumulating tanks with or without passing through a finisher or homogenizer. The residues are discharged from the lower end of the screens and are sometimes used in preparing pomace jams or beverage bases.

Sweetening and Blending. Although blending of juice to secure a desired sugar; acid ratio, and flavor balance is ordinarily accomplished by blending fruit going to the extractors, juice may be accumulated in 90 to 500 gallon tanks after screening, and separately extracted juices, from different lots or varieties of fruit, may be blended at this stage. Dextrose or sucrose may be added if desired. If juice is to be blended or sweetened, in this manner, two or more tanks are required to permit continuous operation. These tanks are preferably located in cool rooms, and juice should not be permitted to stand in the tanks for more than a few minutes.

Deaeration. Extracting, screening and sweetening incorporate air in the juice which may lower the ascorbic acid (vitamin C) content, and damage the flavor and keeping quality.

Deaeration of citrus juices is accomplished by agitating the juice or exposing it in thin films under a high vacuum. A vacuum is ordinarily drawn, by means of a pump or steam ejector, upon a closed stainless steel shell, and juice is admitted near the top. Impact may be provided by an arrangement of nozzles, cones or plates, or by throwing the juice against the side of the vessel through perforations in a rapidly rotating disc. The juice may be exposed in thin films by allowing it to cascade over a series of baffles.

A vacuum of not less than 27 inches should be used if the juice going to the deaerator is at 70° F. A higher vacuum should be used for cooler juices as the solubility of oxygen increases at lower temperatures. Two stage deaeration with a slight warming of the juice between the first and second stages permits increased reduction of oxygen content and greater capacity for deaeration equipment.

Deaerators should be installed not less than 10 feet above the pump used to withdraw the juice. In some plants deaerators are elevated 30 feet above the pump in order to increase capacity and reduce the load upon the pump.

Filling. Bottom fillers are commonly used to minimize the mechanical incorporation of air during the filling operation. Defoamers to remove foam from the surface of the juice in cans, consist of a blast of steam or inert gas. Gas flow and vacuum sealing machines are used to remove air from the head space which must be left to accommodate for expansion during freezing. In gas flow machines a mixture consisting of two-thirds nitrogen and one-third carbon dioxide may be used. Nitrogen is less soluble than oxygen, carbon dioxide is more soluble than oxygen, but carbonation of the juice should be avoided as this tends to give the juice a fermented flavor.

Containers. Glass and tin containers with gas tight seals are best for citrus juice, as they afford maximum protection against oxidation and drying. Plain and enamel cans are used. Other containers consist of slip top cans, and of

bags or wrappers, made from moisture-vapor proof, transparent films of rubber latex, or lacquered cellophane; these containers usually being placed in waxed cartons, tubs or cups. Paraffin-waxed cardboard containers alone are suitable only for very short storage periods, as these containers permit oxidation and drying of the juice.

Freezing. Freezing should be completed rapidly in order to avoid deterioration and to insure the formation of small crystals which minimize separation of insoluble solids when frozen juice is thawed.

The juice may be frozen to the consistency of slush in continuous ice cream freezers before filling, or may be cooled to 30° F in refrigerated heat exchangers similar to those used for cooling milk. After filling, containers are sealed under a vacuum, or an inert gas is used to remove oxygen from the head space. The freezing process is then completed by contact with refrigerated plates, or rapidly circulated alcohol, brine, fog or air. The rate of heat exchange is ordinarily accelerated by rotation of the containers. The juice is frozen to a temperature of 0° F, then containers are cased and immediately placed in 0° F storage. Storage temperatures should be uniform and should not exceed 10° F. The lower the temperature the longer the storage life of the product.

Frozen Orange and Grapefruit Sections. Mandarin orange and Marsh, Duncan, Pink and Ruby grapefruit sections have been canned in 40 and 50° brix syrup for many years. Tests have demonstrated that these products may also be preserved by freezing, but the flavor advantage of the frozen over the canned product is less conspicuous than the case of citrus juices.

In preparing sections for freezing, the peel of clean, sound, mature fruit is removed by hand, after it has been puffed by immersing the fruit in steam or hot water for from 2 to 5 minutes, depending upon the thickness of the peel. The sections may then be broken apart by hand and the membrane removed by lye peeling, or the outer membrane of the whole peeled fruit may first be removed by lye peeling. Lye peeling is ordinarily accomplished by immersion for 20 seconds in 1 per cent boiling caustic soda solution, followed by vigorous rinsing in clean, cold water. In some plants a final rinse of dilute, chilled citric acid solution is used to remove the last traces of caustic soda. The sections are placed in containers containing 40 or 50° brix syrup, rapidly frozen and stored at temperatures not to exceed 10° F.

Storage, Transportation, and Preparation for use. Storage at uniform temperatures prevents repeated thawing and refreezing of concentrated sugar syrup. This intermittent thawing increases the size of ice crystals, damaging the texture, resulting in mushiness of sections and excessive separation in juice. Special precautions to maintain uniform temperatures are desirable during transportation of products in refrigerated cars.

Products are usually defrosted for use by placing in refrigerators at 40° F just long enough to allow only a few ice crystals to remain in the product at the time it is served. If this practice is carefully followed the flavor of the juice should compare favorably with that of similarly

chilled, freshly extracted juice. The time required to substantially thaw the juice varies with the size of the containers and the temperature in the refrigerator. For more rapid defrosting cans may be agitated under sprays of cool (never warm) water until thawing is substantially completed.

Summary. Methods for preserving fruits and juices by freezing are described.

The importance of proper storing and handling is indicated and attention is called to the fact that the success of commercial operations has depended upon the establishment of definite markets prior to the packing of the product.

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